

MAINTENANCE ISSUES, RECOMMENDATIONS, AND SPECIFICATIONS

This section is a compilation of major maintenance recommendations for all trail field assessments in January and March, 2003. The issues and recommendations have been prioritized to help guide the park in implementation of work. The subsequent sections of this chapter contain detailed specifications on how to accomplish these projects. The highest priority maintenance needs relate to large volumes of water, moving at high speed along or across the trail, causing extensive erosion and gullyng of the treadway. Repairs needed include:

- Construct and maintain water dips to direct water off of the trail
- Install, reset and maintain water bars to hold the trail tread in steep sections and direct water off of the trail
- Install and maintain culverts to direct large volumes of water under the trail
- Restore and maintain bench cut trails to eliminate gullies
- Install checks to stabilize tread where water flows directly down the trail
- Construct log cribs and walls to stabilize heavily eroded trail sections

Extensive ongoing routine and cyclic maintenance is also needed to preserve the trails. In some cases work is needed to ensure that historic constructed features are not lost. Recommendations are provided to:

- Obscure closed trails to prevent further erosion of unstable areas and eliminate confusion by trail users
- Reroute short segments of trail that are heavily damaged and where an alternate route is more stable
- Trim trail-side vegetation and revegetate eroded areas to preserve the trail corridor
- Build or maintain wall-less causeway
- Apply gravel tread in combination with waterbars, checks and log cribs, to raise the level of the tread back to its original height and improve drainage and durability
- Rehabilitate stone pavement where historic stonework is falling apart
- Rehabilitate stone walls where historic stonework is collapsing

The issues identified at Valley Forge NHP, recommended actions, detailed specifications, and strategies for implementation are organized by feature type as outlined below:

Issues: A description with text and photographs of the conditions observed in January and March of 2003.

Recommendations: A description of proposed actions by the field assessment team.

Specifications: A description with diagrams and altered photographs of the materials, dimensions, construction techniques to be used.

Implementation: A description of the appropriate use of trail professionals and volunteers for construction projects and ongoing maintenance tasks. Diagrams and altered photographs are included to help train volunteers on best practices for trail work.

The chapter is organized according to a general approach to trail maintenance, first looking at the overall trail characteristics associated with the location of the route and the types of vegetation, then looking more closely at the composition of the treadway and the appropriate drainage systems. The final section addresses the retention and stabilization of slopes, above, below and in the trail treadway.

1. Route

1. Obscure Closed Trails
2. Reroute Short Segments of Trail

2. Vegetation

1. Trim Trail-sides and Revegetate Eroded Areas

3. Treadway

1. Restore and Maintain Bench Cut Trails
2. Build and Maintain Wall-less Causeway
3. Apply Gravel Tread
4. Rehabilitate Stone Pavement

4. Drainage

1. General Guidelines
2. Construct and Maintain Water Dips
3. Install, Reset, and Maintain Water Bars
4. Install and Maintain Culverts

5. Retaining Structures

1. General Guidelines
2. Install Checks
3. Construct Log Cribs
4. Construct Log Walls
5. Rehabilitate Stone Walls

Many of the specifications were obtained from the draft Cultural Landscape Report for Acadia National Park, Historic Hiking Trail System of Mount Desert Island, which was prepared by Christian Barter, Margaret Coffin Brown, J. Tracy Stakely, and Gary Stellpflug. Diagrams from the Acadia National Park specifications were prepared by Sarah Baldyga.

1.1 ROUTE: Obscure Closed Trails

Issue: Some trails follow routes that are not safe or reasonable to maintain. Many trail users continue to use these routes. Visible evidence of use encourages others to follow. Closed trails include (for trail location, see Drawings 1 and 2):

- Baptist Road Trace below Chapel Trail intersection
- Betzwood Trail Network
- Chapel Trail A unauthorized trail down ravine
- Fatland Trail
- Horse-Shoe Trail C
- Impoundment Trail
- Mount Joy Trails E, K, L, M, and N
- Mount Misery Trail D
- Nursery Trail Network
- South River Trails A and B
- Superintendent's Trail unauthorized spur to Fatland Trail
- Vernal Pool Trail Network
- Wayne's Woods
- Yellow Springs Trail Network

Recommendation: To minimize confusion for trail users, obscure closed, social, or unauthorized trails with random placement of large logs and branches that blend into the natural landscape. Also distribute leaf duff and organic matter to disguise and revegetate the treadway. Do not disassemble historic stonework or regrade historic traces (Figures 4.1-4.3).



Figure 4.1. Entrance to unauthorized trail off Chapel Trail A requires ongoing brush covering to discourage use.



Figure 4.2. On closed Horse-Shoe Trail C, randomize debris and logs and distribute duff and other organic material to better disguise and revegetate treadway.



Figure 4.3. On closed Mount Misery Trail C, use larger dead trees with lots of branches to discourage

Specifications: Move large trees trunks and branches across the trail that require more than one person to relocate. Use a Griphoist® or other pulley system to move large objects (See Appendix E). Place signs at trail heads “Trail Closed, This Trail Has Been Damaged, Give it a Rest.”

Implementation: Trail professionals or trained staff/volunteers should operate pulley and winching equipment. Groups of volunteers can cover entrances to unauthorized trails, hide social spurs, and deter trail braiding by dragging logs and brush, spreading organic debris and leaf duff, and checking trailheads to ensure that signs are not vandalized (Figure 4.4).

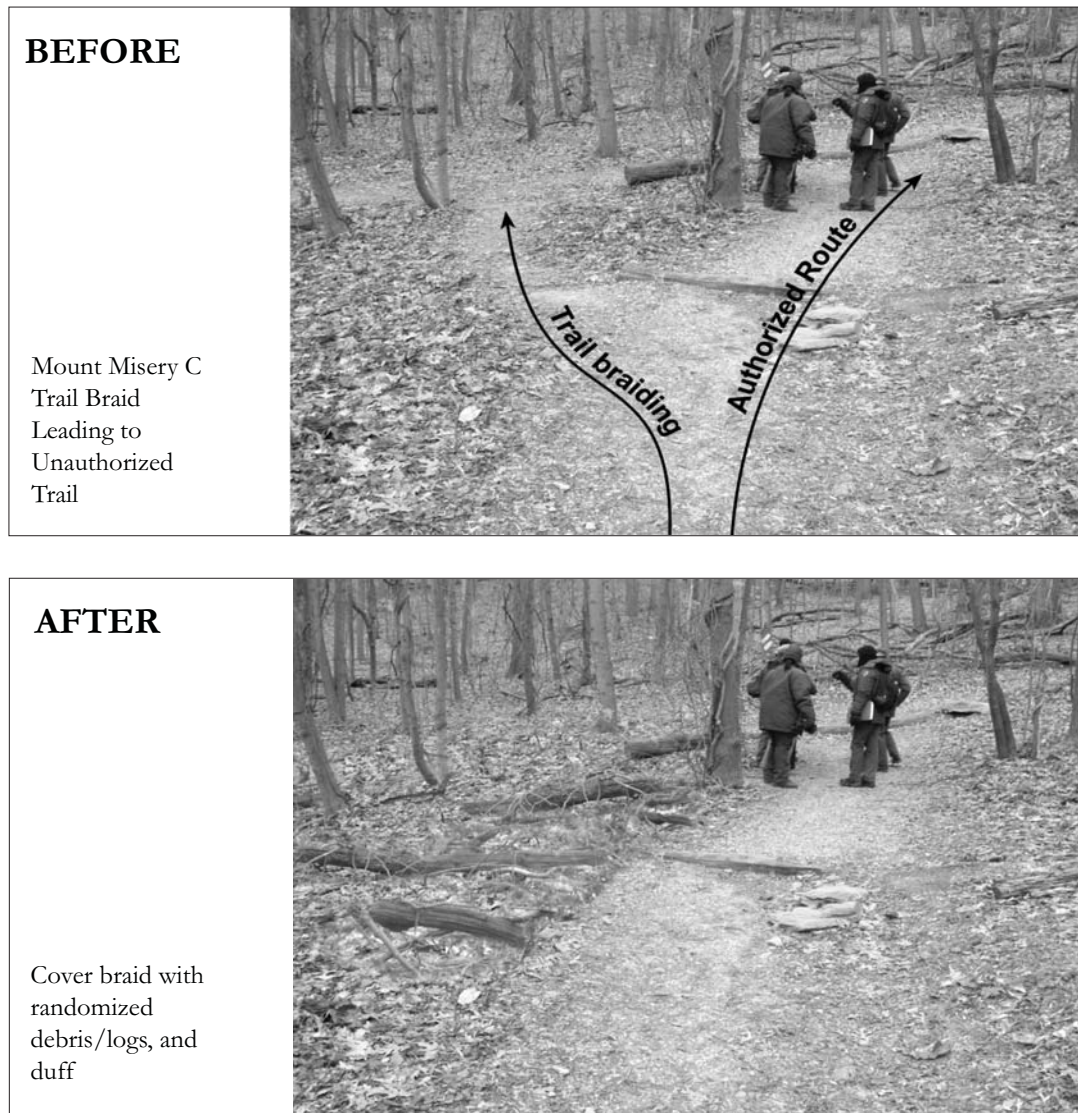


Figure 4.4. Example of a proposed closed spur covering project.

1.2 ROUTE: Reroute Short Segments of Trail

Issue: Some trail alignments are more susceptible to erosion. A trail that travels up the fall-line is likely to have considerable erosion due to use and water flow. A lowland alignment is likely to acquire standing or running water. Preserving a trail alignment that runs up the fall line may require extensive built features that detract from the historic setting. Alternatively, rerouting away from the historic alignment may detract from the historic character of a trail or road trace. In some cases, rerouting may be necessary as a temporary measure until a section of trail can be properly repaired. Rerouting may also be considered as a more permanent solution for some trails. In all cases, the location of the historic trail and all reroutes need to be carefully documented. Locations where short reroutes should be considered include (for trail location, see Drawings 1 and 2):

- Chapel Trail B along west side of private property
- Horse-Shoe Trail A near collapsing dam (Figure 4.5)
- Mount Misery B trailhead at Valley Creek Trail the Upper Forge site (Figure 4.6)

Recommendation: Identify control points or significant locations that relate to the purpose and design of the route. When laying out a reroute, try to retain control points and destinations within the route. Reroute short segments of trail to reduce erosion and preserve the historic setting by not adding extensive constructed features. Document reroutes using GPS technology and do not destroy any historic features such as stonework. Use organic matter to cover the closed section as described on the previous page. Additional reroutes or trail closing may be considered if:

- Important natural resources, such as rare species or water quality, are severely threatened or damaged by the use of the present route and a more sustainable route is identified
- The present route is not maintainable and/or is subject to repeated damage
- The trail is to be made accessible under ADA guidelines and the correct grade cannot be achieved on the present route

Reroutes should be avoided if:

- A substantial amount of important, character-defining historic work exists on the route or segment in question
- The current route is the only viable route on which important historic control points can be reached
- The current route is the only viable route that does not threaten important natural resources
- Any viable new route will eventually develop the same problems as the present route



Figure 4.5. Section of Horse-Shoe Trail A is eroding as stream follows a different course after Hurricane Floyd in 1999, when the stream culvert became blocked and the rising water created an alternate channel around the dam. A short segment of trail should be rerouted away from the stream.

Specifications: Mark reroute with flagging. A grade of ten percent or less is preferable. Avoid routing down the fall line. Add constructed trail features as needed to direct water off of the trail tread. Connect to the existing trail with an arc rather than a right angle to prevent shortcutting. Obscure abandoned trail segment with branches, leaf duff, organic matter and vegetation. Historic work on original alignment should be stabilized and left intact.

Implementation: Trail professionals should flag the new route, determine construction materials needed and document any historic features along the closed segment. Volunteers can obscure the closed segment with logs, branches, leaf duff, and vegetation.

BEFORE

Mount Misery
B leads down
a huge gully
before reaching
Valley Creek
Trail



AFTER

Recommended
stabilization
includes:
rebench the
trail to the left
(west), bring
tread to grade,
build checks
and rubble wall
at turn, install
drainage, then
revegetate area



Figure 4.6. Example of a reroute on short segment of trail.

2.1 VEGETATION: Trim Trail-sides and Revegetate Eroded Areas

The presence or absence of vegetation along the trail contributes to trail character. There are 1,300 acres of woodlands and 1,200 acres of grassland within Valley Forge NHP and most trails travel through woodlands. Trailside vegetation requires routine maintenance to ensure the safety and comfort of trail users.

Issues: Vegetation has grown into the trail causing hikers to move to the outside shoulder of the trail, widening the treadway. Where trails have widened, there is increased erosion. In redefining the appropriate trail width, revegetation is needed.

- All open trails should be trimmed according to guidelines for trail brush width and height depending on horse, hiker, or biker usage (Figures 4.7, 4.8)

Recommendation: Prune vegetation, particularly where branches have grown into the trail, causing users to widen the other side of the trail.

Specifications for trailside trimming: The trail corridor should be cleared high enough for a hiker, biker or horseback rider to pass without touching overhanging limbs and brush, approximately eight feet above grade for hiking trails and sixteen feet high for horse trails. Allowance must be made for brush and limbs weighted down with rain or snow, and for the increased height of a snow covered tread. With no exceptions should trails be cleared too wide so as to encourage erosion by trail widening or braiding. Generally, a “V” shaped trail corridor in cross-section is desirable. Width should be determined for each individual trail section. Avoid leaving stubs or sharp points on pruned trees and/or limbs to ensure tree health and hiker safety.

Implementation: Trail professionals should train all volunteers on appropriate trail pruning techniques to prevent excessive removal of vegetation. Volunteers can remove all cut branches and debris from the trail and scatter it completely out of view from the trail. Brush should not be left in unsightly piles. All trails should be monitored yearly for clearing. All trails should be cleared on a cyclical basis, approximately every three to five years. On-going training should be provided for all new workers in corridor clearing, vegetation pruning, and debris removal techniques.



Figure 4.7. Overgrown vegetation on Horse-Shoe Trail A is causing hikers walk on delicate outer edge



Figure 4.8. Vegetation is beginning to encroach trail on Mount Joy Trail F.

3.1 TREADWAY: Restore and Maintain Bench Cut Trails

When a trail leads along a hillside, a bench cut is needed. A bench cut is a cross-slope treadway constructed by removing material from the slope to create a flattened surface. Bench-cut trails require ongoing maintenance to ensure that the bench is outsloped, water flows across the bench, and associated drainage remains functional. Maintenance also involves removing uphill material that has slumped into the treadway where the uphill sideslope meets it, and regrading collapsing banks on either side of the treadway. Defining the tread edges with vegetation, brush and coping stones and barriers are vital in keeping users in the trail, which helps to preserve bench cuts.

Issue: Valley Forge NHP contains many bench-cut trails that have not been maintained. When not maintained a bench-cut trail becomes a gully and berm (Figure 4.9). In some sections the sideslope above the trail has washed into the treadway, narrowing the trail. This forces the trail users to the outside edge of the trail, widening the trail and causing further bench loss and deterioration. Trails with gullied benches in need of repair include (for trail location, see Drawings 1 and 2):

- Chapel Trail A and B
- Horse-Shoe Trail A above switchback and bottling plant
- Mount Joy B, C, D, F, and J (Figures 4.10 and 4.11)
- Mount Misery B
- Valley Creek - small section on slope near intersection with Horse-Shoe Trail A

Recommendation: Sections of damaged bench-cut trail should be restored by removing the berm, regrading the outslope (Figure 4.12), and defining the edge of the treadway with vegetation, coping stones and other barriers. Barriers should be careful to work in conjunction with water bars and dips that are needed where the benched trail runs along a steep slope and water must be directed off of the trail.

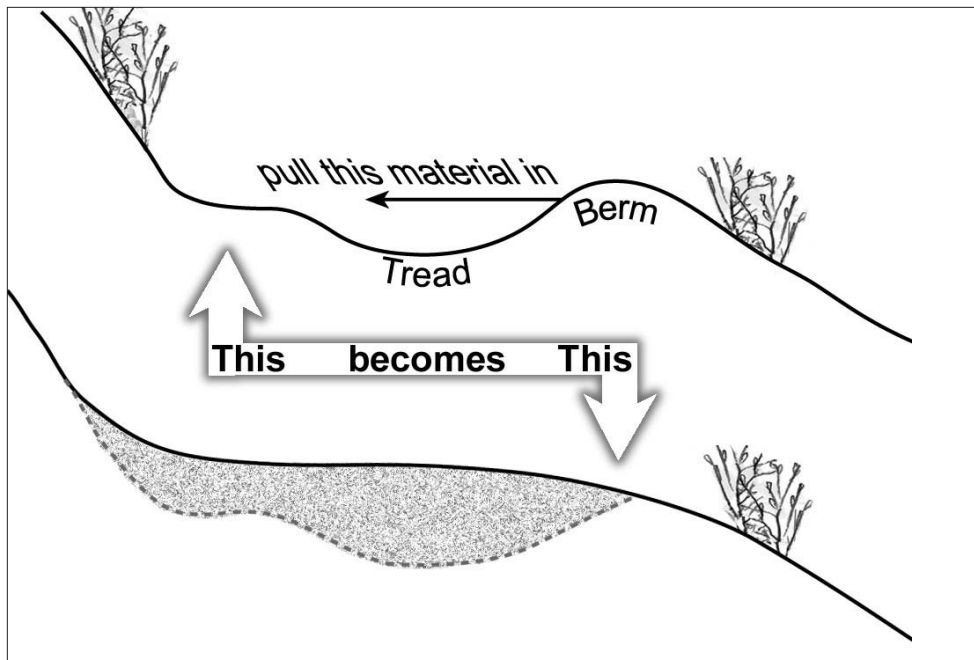


Figure 4.9. A benched trail that has lost its outslope needs to be restored by regrading the berm and adding material.

BEFORE

Mount Joy
F has lost its
bench and
outslope
and is gullying



AFTER

Rebench and
pull in berm,
regrade with
material, drain,
and define tread
edge to keep
users on trail



Figure 4.10. Example of a proposed rebenching project.

Specifications: The tread width should be in keeping with the rest of the trail. The bench tread should have an outslope of one-half inch to one foot of trail width. Where an inside drain is needed the trail should be crowned. To prevent erosion, the bank or sideslope on the uphill and downhill sides of the treadway should be sloped to its angle of repose. This angle will vary depending on soil type, but the maximum slope is 1:1. Collapsing banks should be regraded at shallower angles or, if this is not possible, stabilized with a retaining wall (see 5.5 Retaining Walls). Once regraded the slopes should be planted with vegetation and covered with leaf duff and organic material.

Implementation: Trail professionals should flag the edges and elevation of the desired trail corridor, setting grade stakes at 10-foot intervals to show the height of the new trail grade. They should also determine whether additional material should be hauled into the work site, whether checks, water bars, side drains, or culverts are needed to prevent erosion. Volunteers can regrade the trail and reshape the tread surface by moving soil from the berm to the treadway and haul in materials needed.

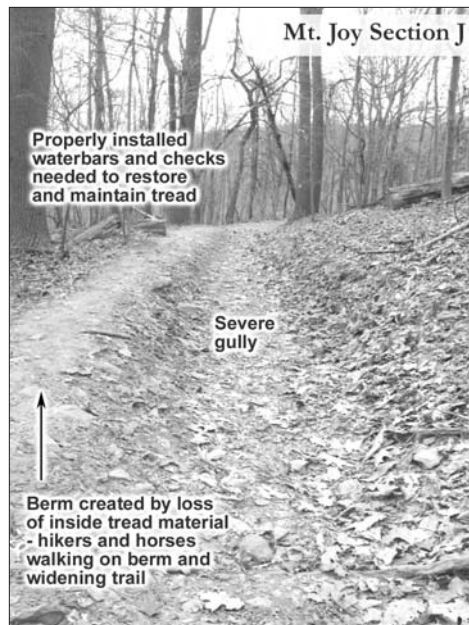


Figure 4.11. A section of trail that needs to be rebenched. Because the gully is long and deep, additional material will need to be hauled in.

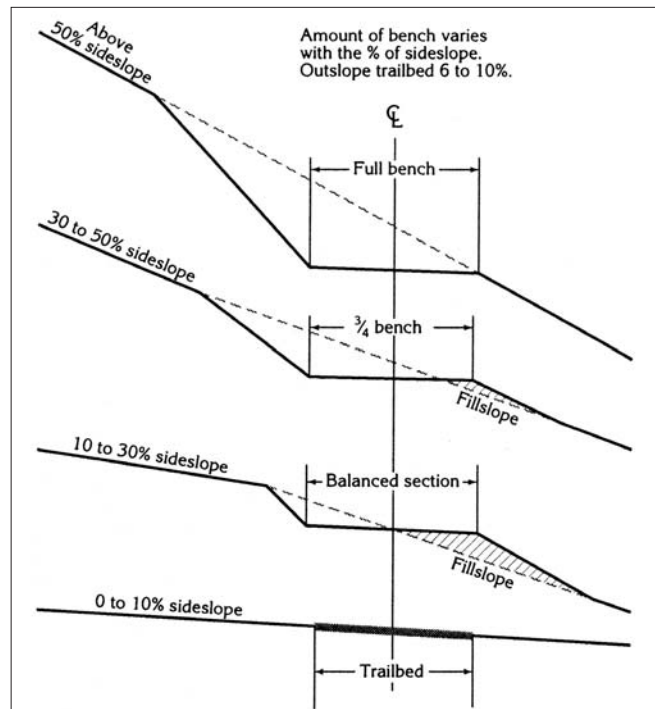


Figure 4.12. Specifications for benches. Where slumping has occurred, regrade slopes to reestablish the trailbed.

3.2 TREADWAY: Build or Maintain Wall-less Causeway

A causeway is a constructed treadway raised above the level of the surrounding area to provide a durable, dry tread through a wet, swampy or meadow area. Causeways are usually constructed in conjunction with cross drainage features such as culverts, subgrade drains or side ditches. Otherwise the raised treadway can be an obstacle to the flow of water. A wall-less causeway is constructed without retaining walls with soil and vegetation serving as the retaining function. Material on the causeway is crowned and should be tamped with a vibrating tamp.

Issue: Many trails at Valley Forge NHP pass through low wet areas and meadows, and there are several existing wall-less causeways at the park that require maintenance of crown material with routine applications of gravel (see 3.3 Apply Gravel Tread).

Trails that require crown maintenance are (for trail location, see Drawings 1 and 2):

- Baptist Road Trace
- Flat section of Chapel Trail B near railroad tracks
- Beginning of Valley Creek Trail near western park boundary (Figure 4.13), and wide area between Lower and Upper Forge

Trails that are candidates for the construction of wall-less causeway are:

- Chapel Trail A in wet meadow area south of ravine
- Superintendent's Trail by farm field
- (If opened) low sections of Vernal Pool Trail or Nursery Trail Network (Figures 4.14, 4.15)



Figure 4.13. Section of Valley Creek Trail causeway that requires routine crown maintenance.

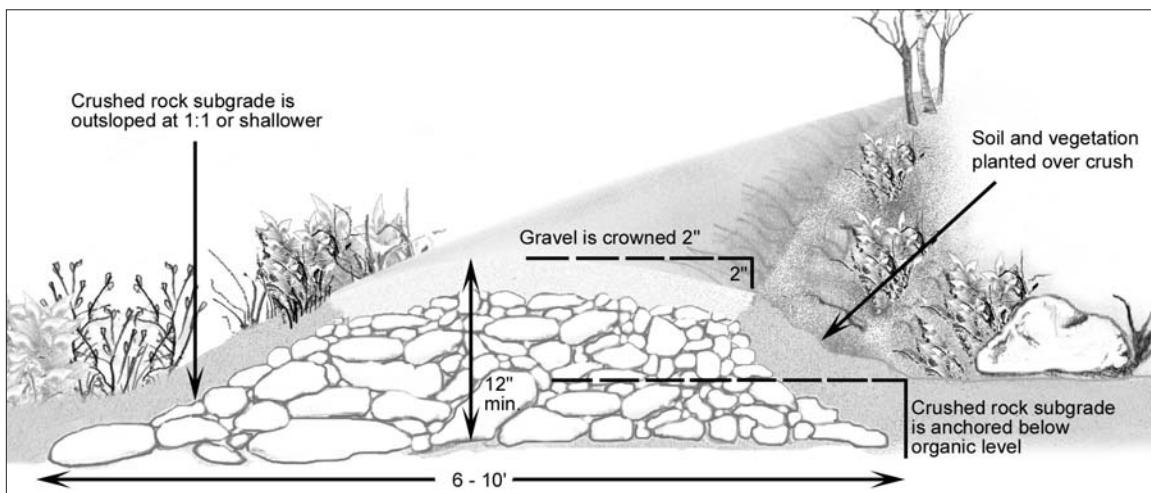


Figure 4.14. Diagram of wall-less causeway construction from specifications for Acadia National Park.

Recommendation: To protect further damage to resources and vegetation, build wall-less causeway, or maintain current wall-less causeway by resurfacing with new material to prevent loss of crown.

Specifications: Wall-less causeway is excavated below the organic layer and six to nine feet wide. A stone rubble base serves as subgrade needs to taper underneath string line outside treadway to its natural angle of repose. Finished causeway will have tread width of four to five feet, and the height of the crown will be at least twelve inches above the surrounding grade.

Implementation: Plans for new causeway construction should first be reviewed by park resource management staff due to excavation necessary for construction. Trail professional should stake proposed edges and height of causeway. Volunteers can haul and place materials.

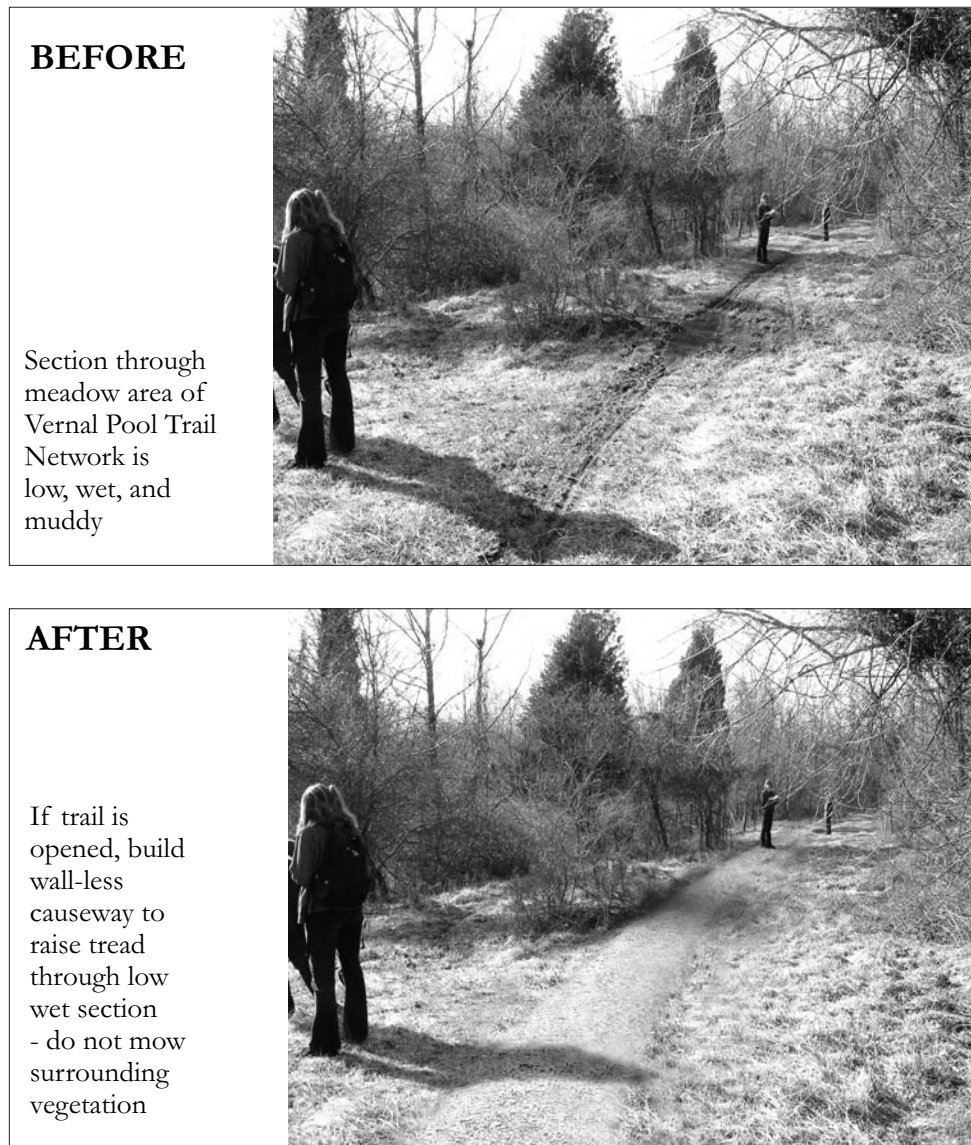


Figure 4.15. Example of a proposed wall-less causeway construction through low wet area of trail.

3.3 TREADWAY: Apply Gravel Tread

Gravel is inorganic material consisting primarily of stones smaller than three-quarter inch diameter. When mixed with soil that contains clay, gravel provides a durable, comfortable tread surface. An aggregate of larger stone pieces is called crushed rock or pea-stone.

Issue: Due to lack of maintenance and insufficient checks and water bars, a substantial amount of material has eroded from trail sections, leaving eroded gullies that collect water, causing further erosion. Sections of trail need to be stabilized with checks and water bars, benched trails need to be regraded, and gullies need to be filled. For many stabilization projects, large quantities of stone and gravel are needed. Trails with major regrading work include (for trail location, see Drawings 1 and 2):

- Baptist Road Trace south of intersection with Chapel Trail
- Catfish Lane Trail where vehicle ruts have damaged tread (Figure 4.16)
- Chapel Trail A and B
- Horse-Shoe Trail A and B
- Mount Joy Trails A, B, C, D, F, and J
- Mount Misery Trail D
- River Trail A, B, C (Figure 4.17)
- Superintendent's Trail
- Walnut Hill Connector
- Wayne's Woods Connector

Recommendation: To protect natural and cultural resources, collecting gravel and stones from banks or streambeds is not appropriate at Valley Forge NHP. For major trail stabilization projects, a tread mix should be ordered from off-site sources and hauled to the work site.

Specifications: Determine the appropriate width for the trail. Excavate the tread to a depth of six inches and remove any organic material. Lay a bed of crushed stone to a height of two inches below the level of the surrounding grade and tamp until stable. Apply gravel/clay mix surface, smooth, and compact with a vibrating tamper until the surface becomes hard. Apply enough material to crown the material at one inch per one foot of trail width to ensure proper drainage, or outslope material on trails that are bench cut. Drainage should be installed alongside or across the tread area.

Implementation: For Valley Forge NHP trails, a tread mix is needed that is similar to the texture and color of local materials. Specifications used for Acadia National Park are included in Appendix E. Working with local stone and gravel suppliers, Valley Forge NHP should develop similar specifications.



Figure 4.16. Catfish Lane Trail needs material to re-grade vehicle ruts



Figure 4.17. River Trail B loses material due to river flooding or material is covered in river silt.

3.4 TREADWAY: Rehabilitate Stone Pavement

Stone pavement is a constructed, continuous stone treadway with individual stones serving as the tread. Stone pavement may be used to cross a rocky area, such as a talus slope, or to harden the surface of a soil treadway on a woodland trail, particularly where there is light water flow. If a small gully has developed, stone pavement can be used to repair a section of trail.

Issue: Remnants of stone paving were found on Mount Joy Trail J, where it is used to stabilize the tread where water flows across the trail (Figure 4.18). The stone pavement was carefully done and possibly dates to the original trail construction on Mount Joy. The stonework has not been maintained however, and is in need of rehabilitation. Similar stonework may be present on Mount Joy Trail I, but further investigation is needed.

- Mount Joy J (and possibly Mount Joy I)

Recommendation: Use local stone to stabilize the trail tread where there is light flow of water across the trail surface.



Figure 4.18. Early stone pavement work found on Mount Joy Trail J.

Specifications: Use local stone of similar size. Excavate the treadway to accommodate the depth of the pavers. Pavers should span the width of the treadway and only the tops should be visible (Figure 4.19). Pavers should be in tight contact with each other and gaps should be chinked at or below tread level to maintain a continuous tread surface. Edges of stonework should be held with larger stones set at an angle towards the paving stones.

Implementation: Trail professionals should supervise stonework to ensure that stones are set securely and evenly to prevent tripping hazards. Volunteers may gather materials and assist with stonework. Routine maintenance is needed to check for and reset loose stones.

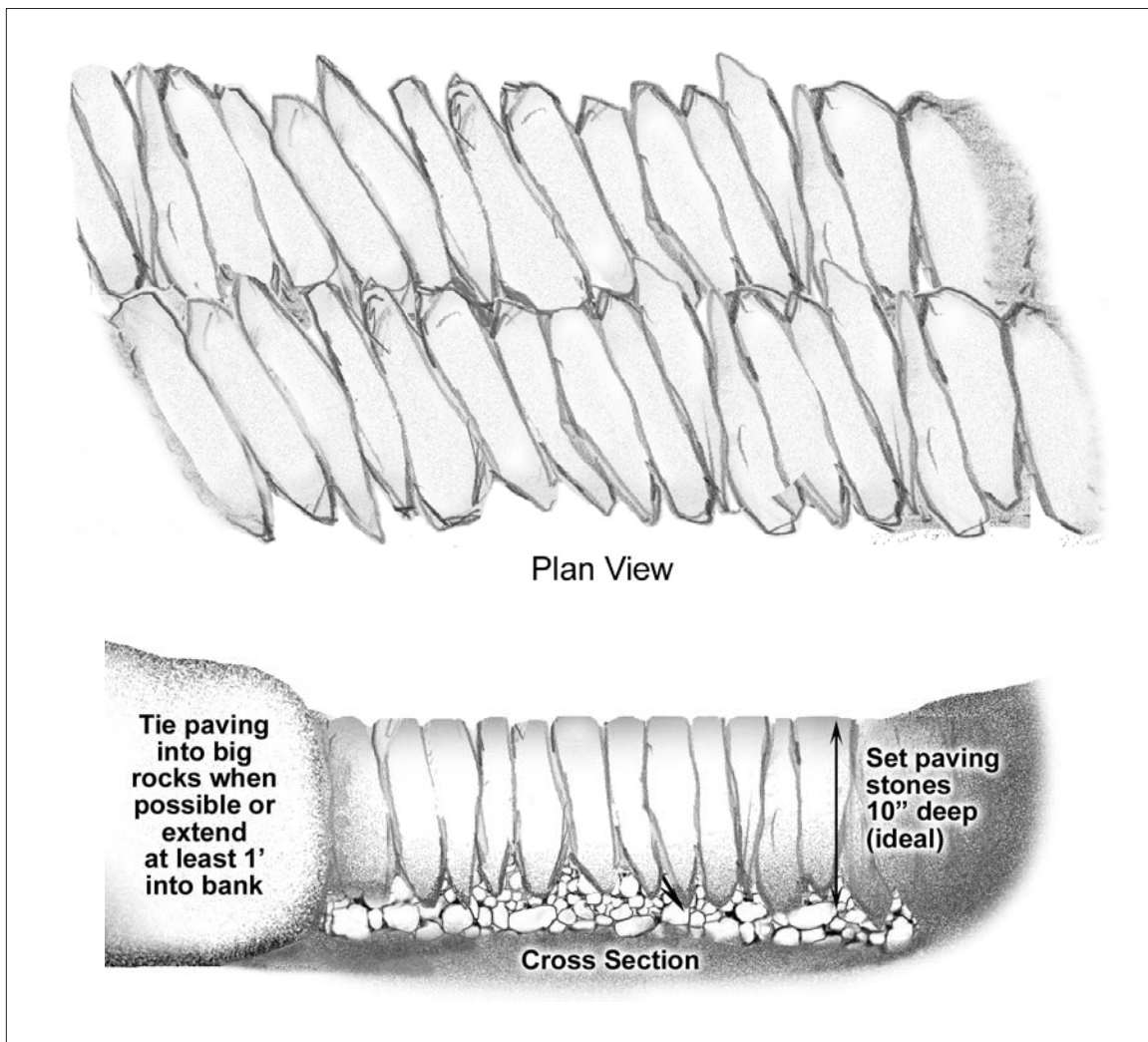


Figure 4.19. Method for stone paving construction using rocks indigenous to Valley Forge NHP.

4.1 DRAINAGE: General Guidelines

Effective drainage, when incorporated into the original design and construction of a trail, can greatly enhance a trail's durability and reduce maintenance (Figure 4.20). At Valley Forge NHP, more drainage features are needed to direct water across and off of the trails. In deciding on the appropriate solution for a drainage issue, consideration should be given to surrounding topography, amount of water flow, and direction of trail slope. Some general guidelines include:

- If water can be diverted without crossing the trail, a **side drain or ditch** may be used (Figure 4.21)
- If water must cross the trail and the flow is light, water can be directed across the trail surface using a **water bar or dip**, or by adjusting the cross slope of the tread
- If water seeps across the trail and the flow is light, water can be directed under the trail surface using **subsurface drainage** such as crushed rock that allows percolation (refer to Figure 4.14 for subgrade diagram)
- If flow is heavy, water should be directed from one side of the trail to the other using a **culvert**, or over a durable surface such as **stone paving** (see 3.3 Treadway). However, a large stream, or one with a consistently heavy flow should not be treated with a culvert. A bridge or other crossing feature may be needed.



Figure 4.20. Pipe culvert under Mount Joy D at Mount Joy E (near Inner Line Drive intersection).

BEFORE

Section of Superintendent's Trail is draining down tread and resulting gully is causing loss of material



AFTER

To rehabilitate, regrade trail and dig a drainage dip across trail (upper center of photo). Then extend ditch down the side of the trail. Provide outlet swales for the ditch wherever possible



Figure 4.21. Example of proposed drainage digging project.

4.2 DRAINAGE: Construct and Maintain Water Dips

A water dip is an angled depression in the trail that diverts water off the trail. If built correctly, both long and shallow, they are unnoticed by trail users and do not disrupt the appearance of the trail corridor. They enhance accessibility of a trail by draining off water without a bar or other obstructive drainage structure.

Issues: Many sections of trail lack proper water drainage. Trails that would benefit from dips are (for trail locations, see Drawings 1 and 2):

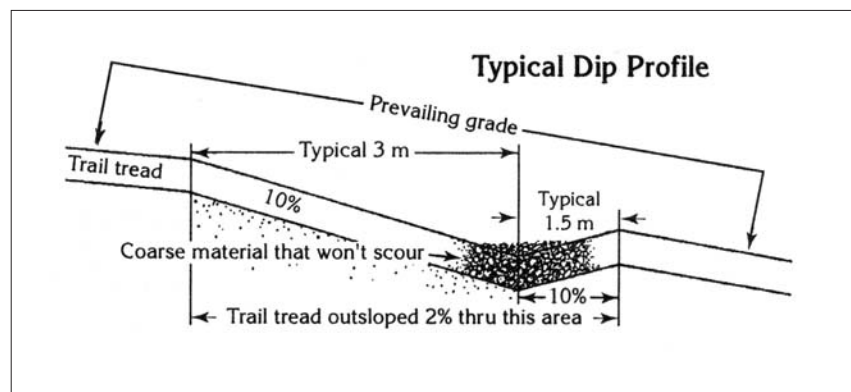
- Chapel Trail A
- Mount Joy F
- Mount Misery A and B
- River Trail - present dips should be maintained
- Superintendent's Trail
- Valley Creek Trail
- Walnut Hill Connector - dip to direct water to culvert
- Yellow Springs Trail Network

Recommendation: Construct dips.

Specifications: The entrance into a water dip starts at the prevailing grade. The dip is angled slightly downslope to direct water off of the trail at a “spill point.” Exact sizes and shapes of water dips will vary with terrain. However, a good target is laid out in Lennon Hooper's, *NPS Trails Management Handbook* (Figure 4.22). The entrance should be ten feet long, the reversal in grade five feet long at a ten percent slope. As in a water bar, a target angle for the depression should be forty-five degrees and should be adjusted according to whether the dip silts-in (increase the angle) or scours (decrease the angle and/or replace with another type of drainage). Slopes into, out of, and back down the trail below the dip should be long and gradual in order to maintain the shape of the dip, provide ease of hiking and remain visually unobtrusive. The depression should be composed of coarse stones that will not wash out. The “spill point” should empty off the trail at a point where water cannot re-enter the treadway, or should empty into an outlet ditch that will carry the water to a place where it cannot re-enter the treadway.

Implementation: Trail professionals should flag the location and dimensions of dips and train volunteers to shape the dips. Dips that continually fill with silt should be rebuilt at a steeper angle. Those that scour should be reset at a shallower angle, or, if the flow is too great, replaced with water bars or another form of drainage. Those dips that flatten or are routinely overrun should, if already built properly, be replaced with another form of drainage. Volunteers can clean water dips annually and, if possible, following severe storms. During cleaning, the original, gradual shape of the dip actually should be restored and the outlet ditch dug out as far as is necessary to insure that water leaves the trail and does not re-enter. Care must be taken not to dig the depression too deep. Re-grade the ends of outlet ditches so that water can smoothly exit. With soil trails, material dug from the depression should be used to back up the water dip, rebuilding the reversal in grade.

Figure 4.22. Drainage dip specifications from Lennon Hooper, *NPS Trails Management Handbook*, 1988.



4.3 DRAINAGE: Reset and Maintain Water Bars

A water bar consists of a depression, or swale, crossing a treadway that is reinforced by a log or row of abutting stones on the downhill side. The purpose of the swale is to divert water off of a sloped trail. The water bar itself retains the swale, prevents erosion, and also diverts water during heavy rains.

Issue: Water bars that have been installed incorrectly or have not been adequately maintained can become tripping hazards. Water bars that lack depressions on the uphill side of the bar to direct water off of the trail will become scoured and rise high above the tread, making them ineffective and tripping hazards. Bars that do not include anchors, which help keep hikers on the trail, will cause the trail to widened around the bars. Water bars that are poorly placed cannot shed water off the trail (Figures 4.23 and 4.24). These conditions were found on (for trail locations, see Drawings 1 and 2):

- Chapel Trail A
- Mount Misery A, B, C
- Horse-Shoe Trail A

Recommendation: Existing water bars should be reset and additional water bars added. Anchor stones, coping stones and log obstructions should be added to guide trail users but not obstruct drainage. Whether log or stone, when properly installed and graded, the top of the bar should be flush with surface on the downhill side of the water bar. Leaf duff can be added along the edges of the trail to better define the trail edges.



Figure 4.23. Existing water bars lack swales, are scoured, and need to be dug deeper into the ground.

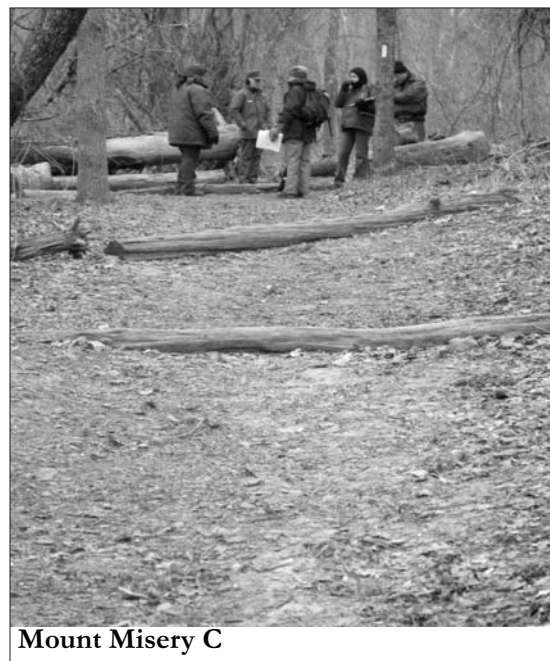


Figure 4.24. Anchor stones, coping stones and log obstructions are needed to keep hikers on the trail, and prevent widening.

Log Bar Specifications: Determine the angle of placement based on the percent slope of the trail segment (Figures 4.25, 4.26, and 4.27).

- A grade along the trail of at least five percent is needed for a water bar to function
- A grade along the trail of fifteen to twenty percent requires a backed water bar
- A grade over twenty percent is too steep and requires steps or checks in conjunction with water bars

The water bar consists of three elements: the bar, the swale and the outlet ditch. The bar in a wood water bar is a single log, set at the appropriate angle, that extends at least twelve inches into the backslope, and to the edge of the trail or beyond it on the downhill side where it meets the outlet ditch. The log should be at least eight inches in diameter. If it is not possible to key the bottom of the log against a natural feature such as a tree (Figure 4.28, 4.29), a stone should be set in the ground at the end of the log to anchor it in place.

“In determining where to place a water bar, select a site where travelers will be discouraged from going around the ends of the bar. A tree or boulder can be a good barrier. If no natural barriers present themselves, embed a few large stones near one or both ends of the water bar to direct traffic toward the center of the trail. When properly installed and graded, the top of the bar should be flush with the surface on the downhill side of the bar.” For more details, refer to *Lightly on the Land: The SCA Trail Building and Maintenance Manual* by Robert Birkby, 2000, 132.

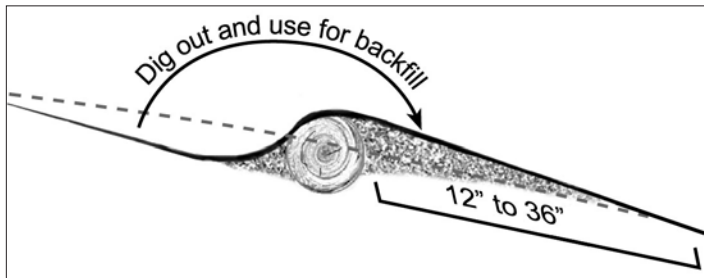


Figure 4.25. Bury the water bar below grade and dig a

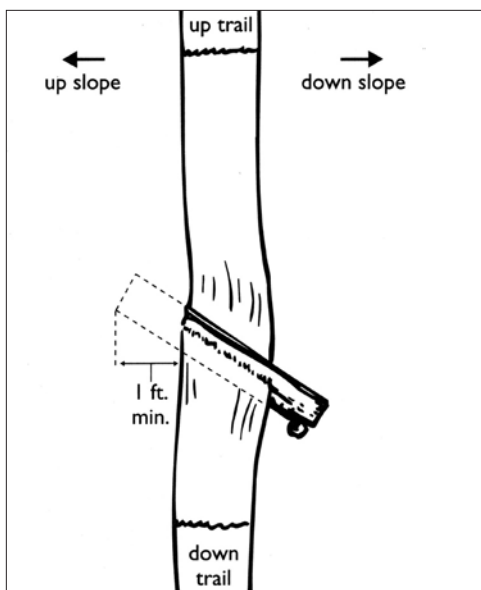


Figure 4.26. Set the angle of the water bar according to the steepness of the slope. From Robert Birkby, *Lightly on the Land*, 2000,

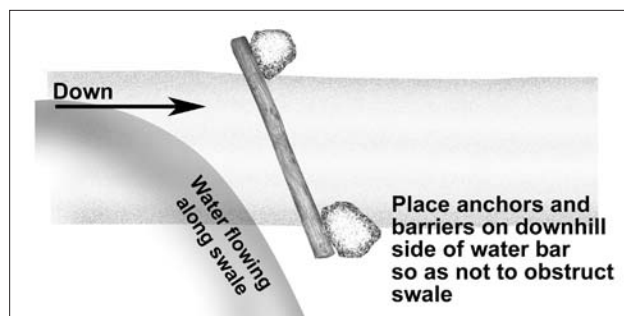


Figure 4.27. Basic water bar guidelines showing placement of anchor stones.



Figure 4.28. This water bar on Mount Misery B is too shallow and directs drainage into a tree.

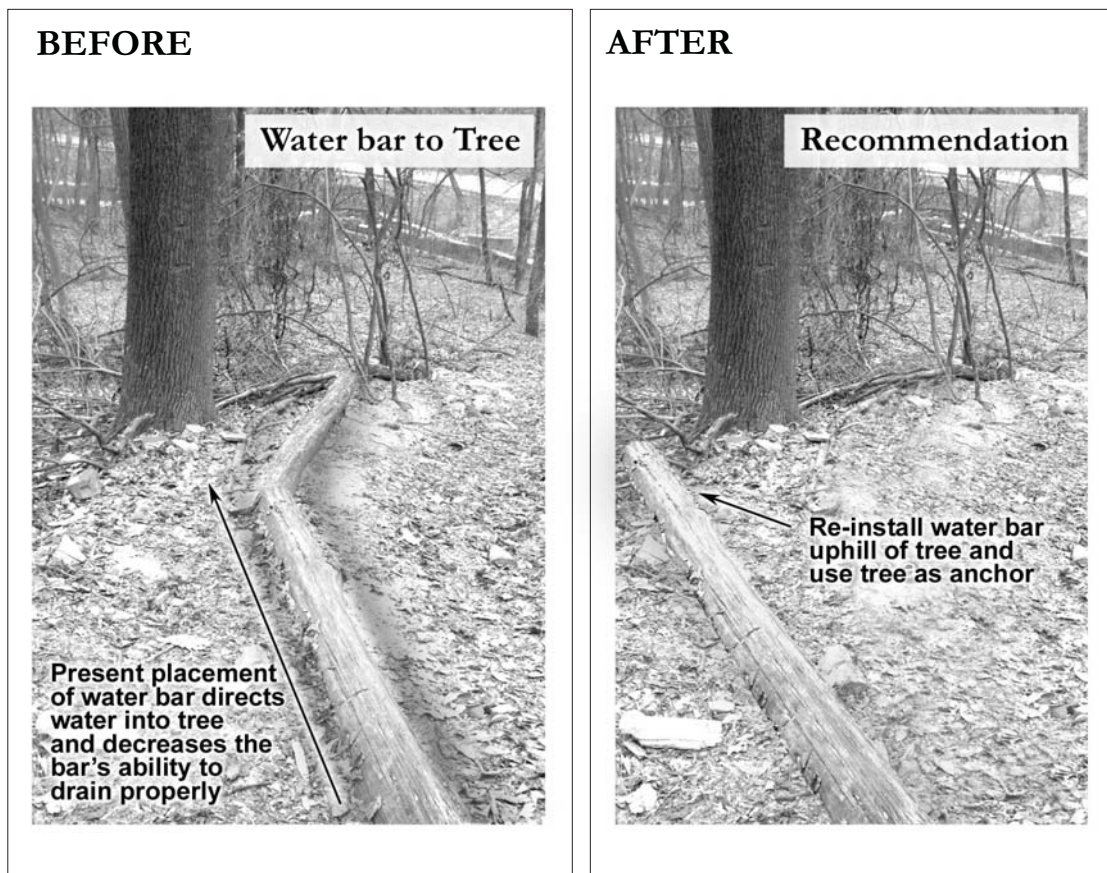


Figure 4.29. Water bar placement recommendation using example from Mount Misery B.

Swale and Outlet Ditch Specifications: The swale or apron is the dip on the uphill side of the bar that directs most of the water off the trail before it reaches the bar itself (Figure 4.30). Construct a drainage swale in front of the water bar and use soil to backfill below the bar. The swale begins sloping toward the outlet ditch about five feet back from the bar, and reverses trail grade to slope up to the bar about a foot from it. Except in times of very heavy flow or poor maintenance, water does not travel along the bar, but down the swale to the outlet ditch. The total depth of the swale (measured from the top of the bar) should be between six and twelve inches, depending on the overall size of the water bar. For more details, refer to *Lightly on the Land: The SCA Trail Building and Maintenance Manual* by Robert Birkby (2000), page 132.

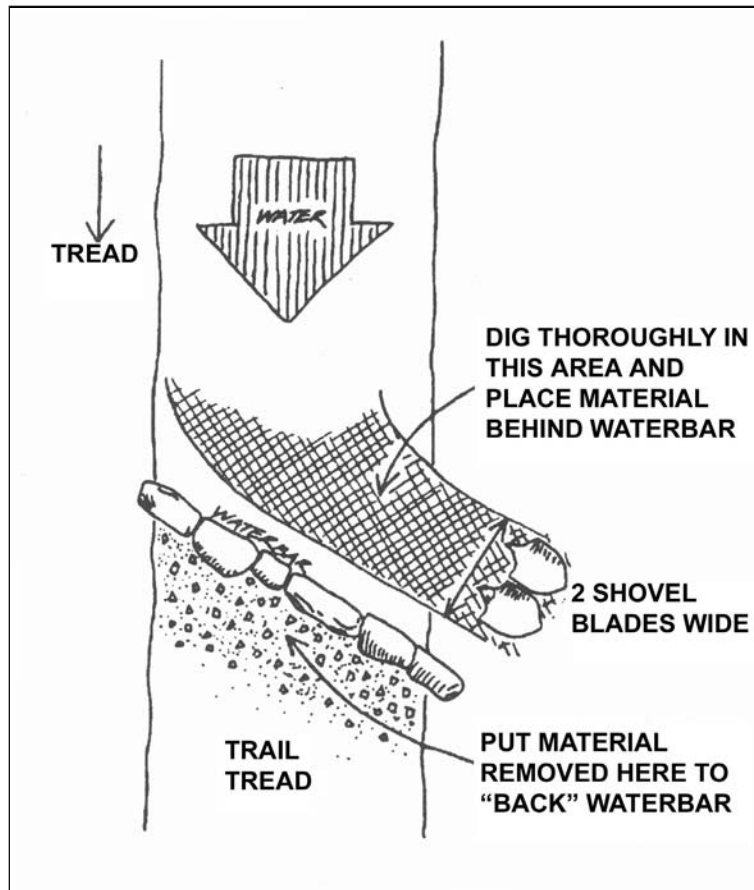


Figure 4.30. Specifications for swale construction (this diagram shows stone water bars, but swale specifications are the same for log). Diagram adapted from Stephen Griswold, *A Handbook on Trail Building and Maintenance*, 1996, 50.

Implementation: Trail professionals should determine the number of waterbars and stake their location and angles. Volunteers can bring in materials to construct the bars. Volunteers can set anchor stones or pins. Volunteers can clean the swales for water bars annually and following severe storms. During cleaning, the original, gradual funnel shape of the apron should be restored. The outlet ditch should be dug out as far as necessary to insure that water leaves the trail and does not reenter. Care must be taken not to dig the apron too deep; the bar should never be fully exposed on the drainage side. Volunteers can regrade the end of the outlet ditch so that water can smoothly exit. With soil tread trails, material dug from the ditch should be used to back up the water bar. Volunteers can reset bars that continually fill with silt at a steeper angle. They can also reset bars that scour to the point of undermining the bar at a shallower angle. Volunteers can check logs for rot, and replace them when they are no longer solid enough to retain the shape of the apron (Figure 4.31). Volunteers can place coping stones and log obstructions, which do not interfere with drainage, to help keep trail users on the treadway. Volunteers can rake leaf duff to define the edges of the treadway.



Figure 4.31. Replace decayed water bars such as this one on Mount. Misery B. The replacement bar should be set below grade with a swale and outlet ditch.

4.4 DRAINAGE: Maintain or Install Culverts

Issue: Several trails in Valley Forge NHP are experiencing heavy water flow across the tread surface and such activity is causing gullies and loss of material (Figure 4.32). Heavy water flow requires more constructed drainage features than those meant for percolating water. Even in areas where culverts are present, debris is often blocking drainage to the culvert and therefore the culvert cannot function properly and wet spots in the trail tread are still occurring (Figure 4.33). Trails that are experiencing heavy water flow across the tread or have culverts in need of cleaning are (for trail locations, see Drawings 1 and 2):

- Chapel Trail at Baptist Road Trace intersection - heavy water flow
- Mount Joy J - heavy water flow
- Mount Joy H at intersection with Mt Joy G - heavy water flow
- Mount Joy N at northern end - material blocking culvert
- River Trail C near General Sullivan's Bridge marker - material blocking culvert
- Valley Creek Trail - material blocking culvert, culvert causing erosion
- Walnut Hill Connector - material blocking ditch, culvert needs dip to direct water to ditch

Recommendation: Culverts are needed to handle heavy, concentrated water flow. Consultation with an engineer is needed to repair or replace ineffective culverts. The outlets of the existing culverts should be stabilized with rocks, retainer devices, and hardened to halt erosion. Once the water is slowed, it should be directed through a culvert located under the trail, and the drainage ditches must be cleared of debris as part of the regular trail maintenance routine. Additional rocks and retaining devices are needed below the trail to prevent erosion near archeological sites.

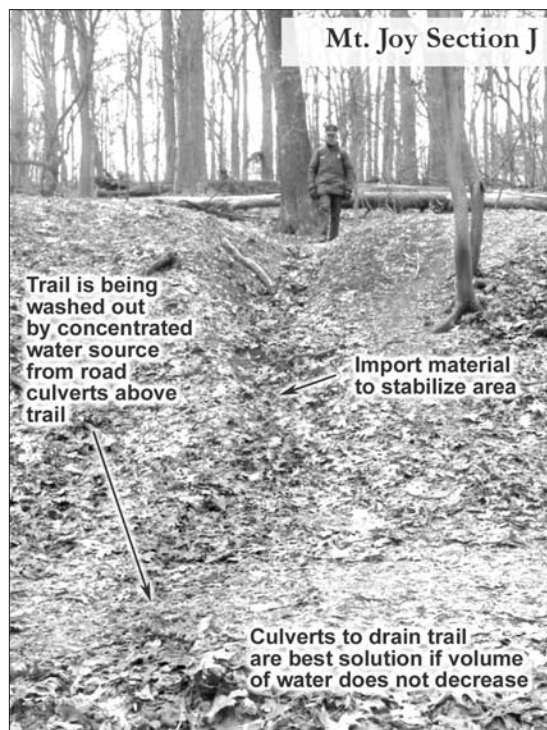


Figure 4.32. Gully from heavy water flow across Mount Joy Trail J.



Figures 4.33. Drainage to culvert on Valley Creek Trail is blocked by debris, and water is draining across trail.

Specifications: Trail culverts and retaining devices should be constructed by professional trail crews. For the trail crossing, where flow is heavy, water should be directed from one side of the trail to the other by a closed or open culvert. For trail sections where less water is crossing the trail, stone paving may be used.

A closed culvert has built sides, a base, and top and directs water under the trail, allowing for an uninterrupted treadway. A pipe culvert or log culvert may be used. To enhance trail accessibility, closed culverts are preferable. A catch basin on the uphill side of the culvert catches debris carried by fast flowing water, preventing debris from flowing into and clogging the culvert.

An open culvert has built sides and usually a stone base, but no top, resulting in an interrupted treadway. Sides may be logs, single-tier retaining walls. Open culverts are not desirable for ADA accessible, bike, or horse trails.

For closed culverts with pipes, dimensions are dictated by width of trail and amount of water flow. Pipe diameter should be at least eight inches to facilitate cleaning. The ends of the pipe should be set back two to four inches from the outside edges of the header walls (Figures 4.34 and 4.35).

Stone rubble is laid in the drainage channel beneath the pipe. One pipe should be laid across the trail following the angle at which the water crosses the trail. Rubble is packed around the pipe to secure it and at least six inches of subsurface material is laid over the top to reduce frost heave.

The pipe should be obscured and protected at each end with a stone headwall. Headwalls should consist of two retaining walls, often each consisting of a single stone, one on each side of the pipe, with a single stone lintel across the top. The lintel should slope in toward the trail to hold gravel, and should be supported by the stone walls, not the pipe. Side retaining walls should be anchored well below the stone rubble base. Stone sizes will vary depending on the trail, but care should be taken that headwall and lintel stones are compatible in size and texture with existing work on the trail.

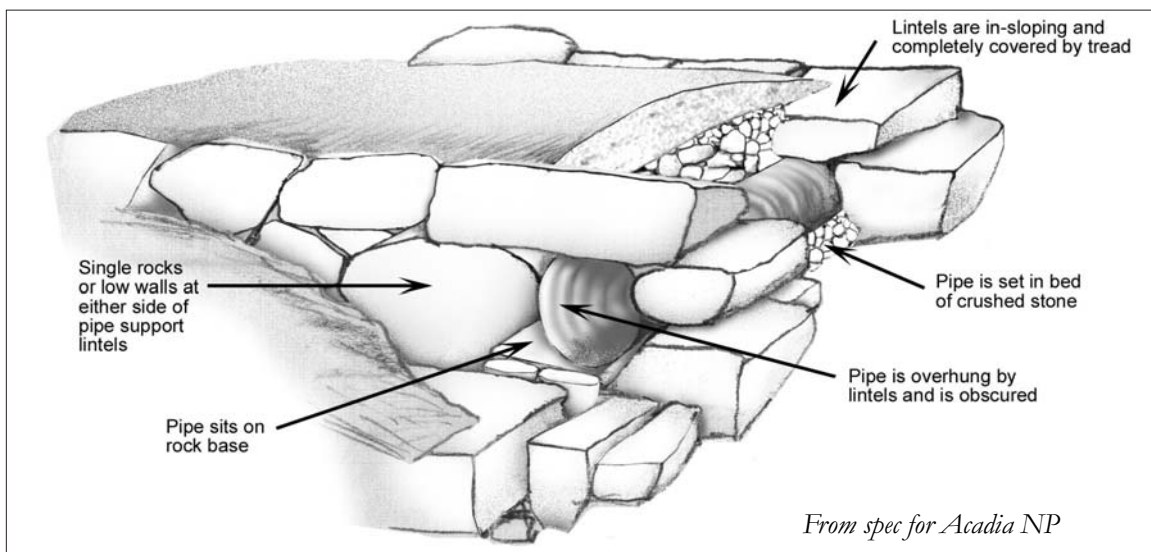


Figure 4.34. Specifications for a pipe culvert.

Implementation: An engineer should be consulted to stabilize the road drainage before repairing the trail. An engineer or trail professional can determine the appropriate size and construction methods for the trail culvert and catch basin, and set the grades for the culvert, catch basin and headwall. Volunteers can assist with the excavation and construction of the culvert and regrading of the treadway. Volunteers can annually clean all types of culverts, catch basins and associated inflow and outflow drains by removing silt and gravel build-ups. Open culverts with gravel or soil bases should be cleaned to the level consistent with drains flowing into them; care must be taken not to dig too deep, this could expose and weaken the sides of the culvert. Outflow drains should be cleaned and re-dug as far as necessary to ensure that water flows unimpeded from the culvert. Dams in outflow drains can cause water to back up onto the trail, or ice to freeze inside the culvert and destroy it. For pipe culverts, reset pipes that have been lifted by ice and resurface the treadway.

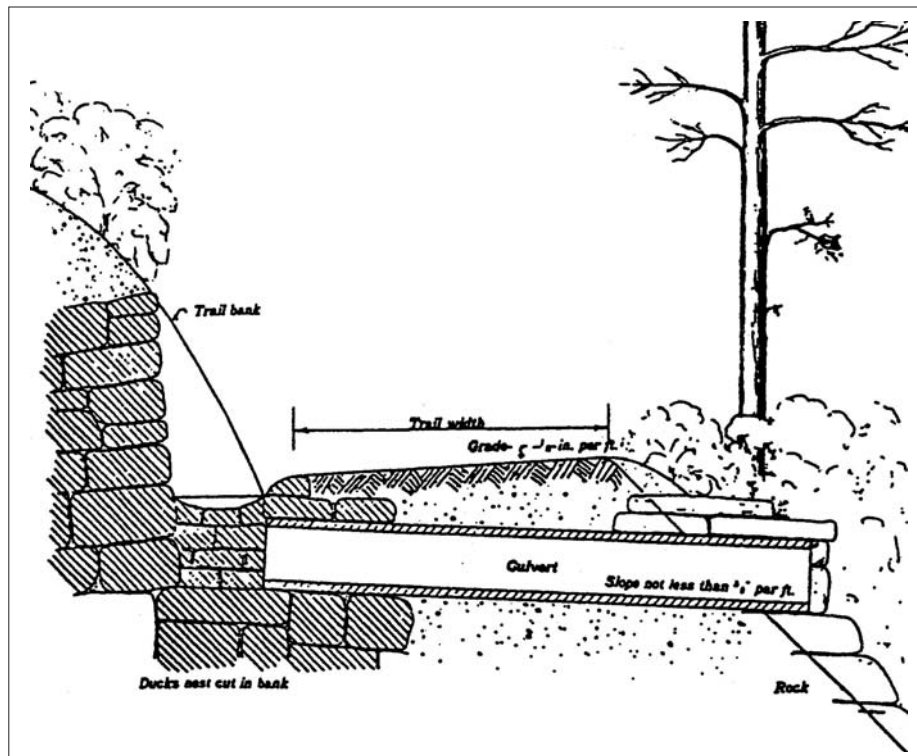


Figure 4.35. Civilian Conservation Corps specification for a closed culvert from Guy Arthur, *Construction of Trails*, 1937.

5.1 RETAINING STRUCTURES: General Guidelines

Retaining structures such as **checks**, **log cribs** and **log** and **stone retaining walls** are all features that maintain trail quality and safety in areas of gully damage, steep slopes, or heavy user traffic..

Each of these features serves a different type of retaining function. **Checks** are built into the tread and are buried at tread height. They hold back the tread material, preventing erosion and/or gullying of the trail surface. **Log cribs** can be built inside the trail sometimes as steps in conjunction with checks, or they can be built as walls to retain the downhill or uphill side of the trail. **Log and stone retaining walls** also retain tread or hold back soil on the downhill or uphill side of the trail, and are often used with bench construction.

Generally, if properly constructed, stone is the most appropriate material to use as retaining structure material. However, in some cases log structures, including log checks and log cribs, may be used (Figure 4.36).



Figure 4.36. Deteriorating stone check on Horse-Shoe Trail A has been backed with a log retainer bar.

5.2 RETAINING STRUCTURES: Install Checks

Checks are logs or rows of stones used in the trail to retain the treadway on slopes with a grade less than twenty percent. They are often used to rehabilitate an eroded area where the original trail surface has washed away and a gully has formed.

Issue: Many Valley Forge NHP trails are gullied and need extensive repairs. Existing stone checks on Mt Misery need repairs (Figure 4.37). Trails with gullies or tread retention issues that would benefit from log (Figure 4.38) or stone (Figure 4.39) check treatment are (for trail locations, see Drawings 1 and 2):

- Chapel Trail A
- Horse-Shoe Trail A
- Mount Joy B, D, G, H
- Mount Misery B and C

Recommendation: Construct checks to repair gullies or retain tread material on steep slopes.



Figure 4.37. Check on Mount Misery C that needs repair. The trail is washing out above and below and causing a gully down the treadway.

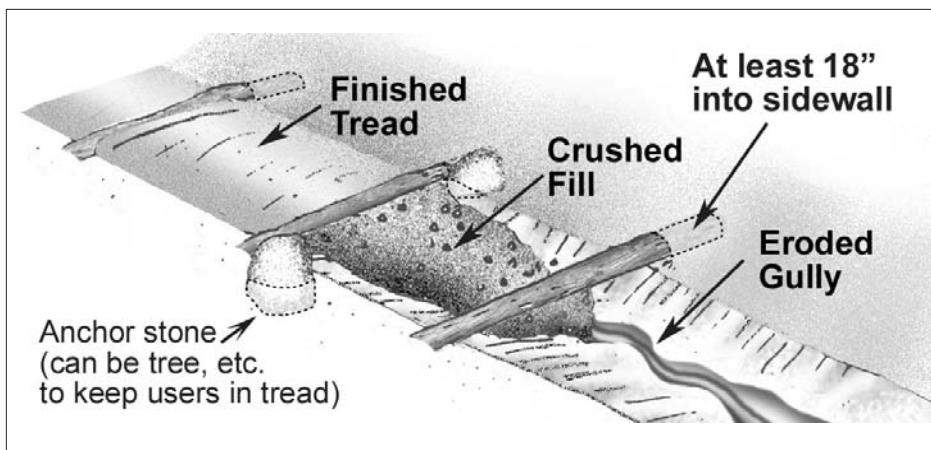


Figure 4.38. Diagram for log checks. Adapted from Griswold, 1996.

Specifications: Check logs or rows of stones are set perpendicular to the trail. The checks are backfilled with rubble and then covered with a top coat of tread material. To prevent failure of the checks due to continued erosion or a lack of maintenance, the bottom of each check is placed at an elevation below the top elevation of the preceding downhill check. The checks act as “hidden steps” underneath the tread surface, holding back, or “checking” the uphill fill material. In worst-case scenarios where tread material wears away and is not replaced, checks hold the remaining treadway in a series of flat terraces (Figures 4.39 and 4.40).

Implementation: Trail professionals should determine the location and type of checks to be installed. Trail professionals can supervise construction of the checks by volunteers. Volunteers can also haul and install materials including check rocks or logs, rubble fill, and surface materials.

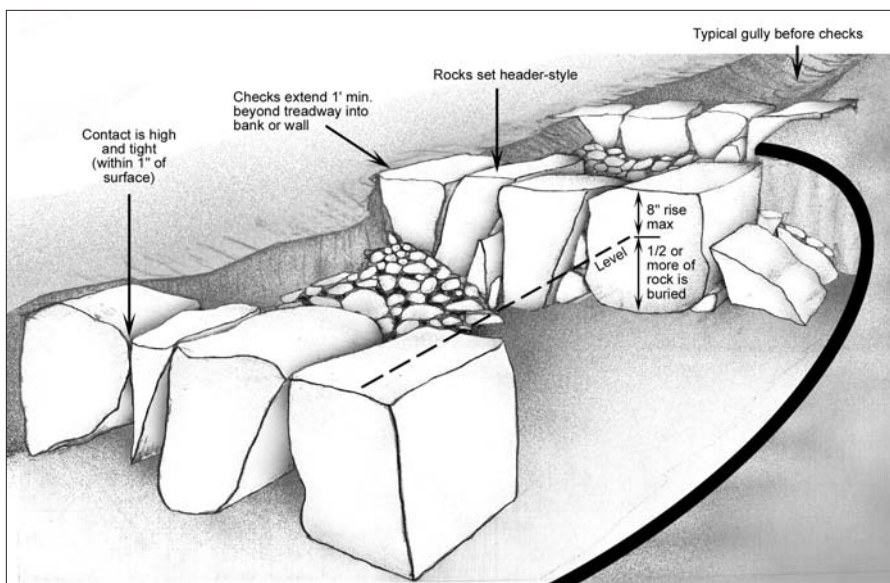


Figure 4.39. Stone check specifications for Acadia National Park.

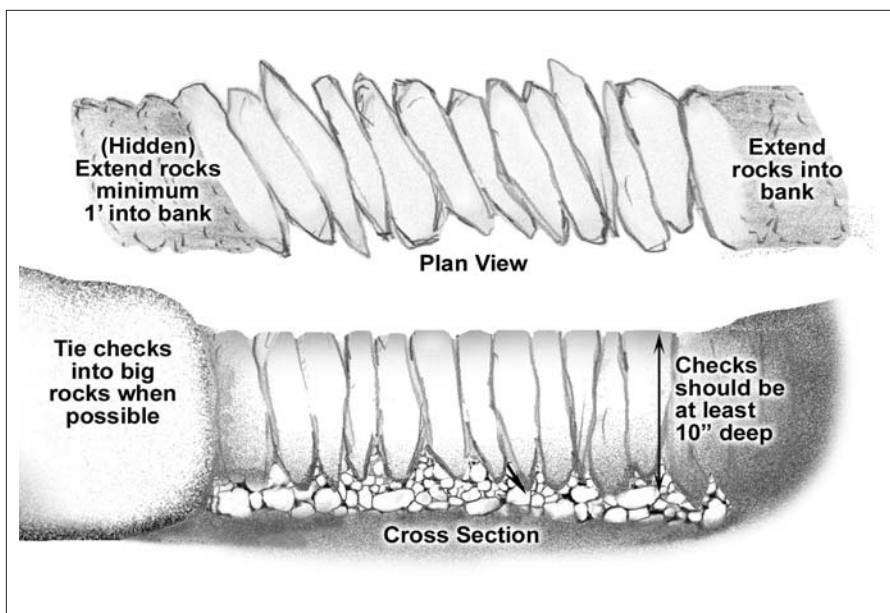


Figure 4.40. Constructing stone checks with small flat rocks indigenous to Valley Forge NHP.

5.3 RETAINING STRUCTURES: Construct Log Cribs

Log cribs are retaining structures consisting of interlocked logs. They may be treadway cribs, which are located in the trail's treadway itself, act as checks to retain the tread, and sometimes serve as sidewalls. They may also be wall cribs, which serve as retaining walls above or below the treadway (see .

Issue: There are several steep eroded segments of trail in Valley Forge NHP where log cribs and steps are needed to stabilize the tread. These include (for trail locations, see Drawings 1 and 2):

- Horse-Shoe Trail A above bottling plant (Figure 4.41)
- Mount Misery B near Valley Creek Trail intersection
- Mount Joy D where severe gully is up to five feet deep (Figure 4.42)

Recommendation: Repair heavily eroded steep sections with log cribbing.



Figure 4.41. Segment of Horse-Shoe Trail A in need of log cribbing.

BEFORE

Massive gully on Mount Joy D is up to five feet deep



AFTER

Haul in material to bring tread to grade and stabilize area and then build crib steps with checks to retain material



Figure 4.42. Example of a proposed crib step and check project.

Specifications for tread cribs: Logs should be structurally sound and greater than four inches in diameter. All joints should be notched, using either flat or saddle notches and spiked. Tread cribs consist of side-pieces, laid along the edge of the tread way, and cross-pieces, or checks, laid across the treadway. The top of the crib should be at or just above the level of the ground at either side of the trail at the edge of the gully. If the gully is deeper than the width of the crib logs, then it should be filled with stone rubble to the appropriate height. Side pieces are set at the edges of the desired treadway width. The slope of the side pieces should not exceed five percent to prevent erosion between checks. If the gully is wider than the desired treadway, the outsides of the crib should be filled with stone and soil and revegetated.

Cross-pieces may be set either on top of or underneath side-pieces (Figure 4.43). If possible, they should be set on top to allow room for vegetating over the side pieces. However, when the cribbing is below the level of the surrounding ground (which should be avoided where possible), cross-pieces can be set below the sides.

The rise between cross-pieces should not exceed one foot. Cross-pieces should be backed with substantial stones that extend into the ground deeper than the height of the next cross-piece below them, so that if the tread erodes to the level of the step below, undermining will not occur. The top surface of cross-pieces should be flattened with a chainsaw or ax to provide a stepping surface.

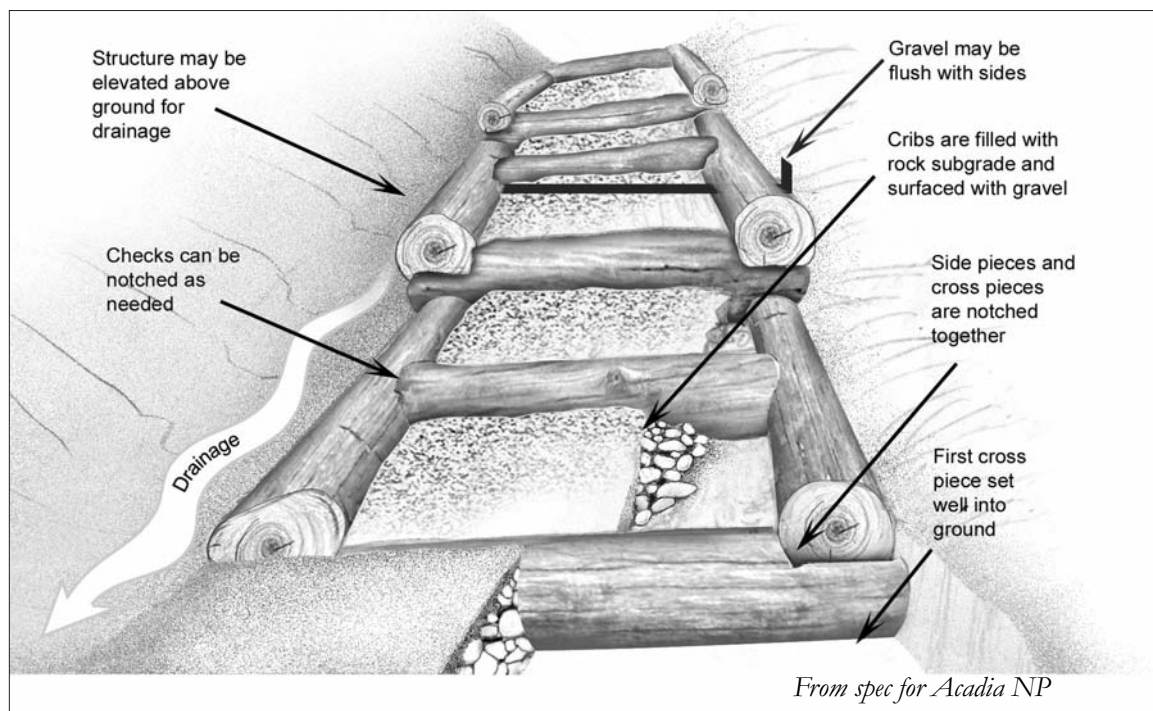


Figure 4.43. Detail of crib steps with checks.

5.4 RETAINING STRUCTURES: Construct Log Walls

Multi-tiered or single-log retaining walls are excellent ways to support the treadway, however they are not as permanent as stone retaining walls if the stone walls are constructed correctly (see 5.5 Stone Walls). Single-log retainers should be well-anchored and are a good method of trail definition and retention in areas in which the slope downhill from trail edge is not experiencing excessive erosion (in that case, a multi-tiered wall would be more appropriate).

Issue: Log retaining walls should be added in some locations. Some existing log retaining walls are being undercut, resulting in erosion of the trail shoulder (Figure 4.44). Locations include:

- Chapel Trail A where tread is eroding down steep bank
- Mount Misery Trail B where current retainer logs are being undermined

Recommendation: Install single retaining logs or multi-tiered log retaining wall in areas where trail is threatened by steep banks along trail.

Specifications: Multi-tiered retaining walls are necessary when trail runs along steep slope and treadway is narrow or hikers are walking near edge to be closer to views or water areas (Figures 4.45).



Figure 4.44. This retaining bar and water bar on Mount Misery B are being eroded. To prevent undermining of the logs, reset the water bar to the correct depth and at the grade of the trail on the uphill side. Solidly set swale outlet stones between water bar and retaining bar and make sure stones have good contact both with each other and with the logs.



Figure 4.45. Multi-tiered Log Retaining Wall. From Birkby, 2000, 195.

Specifications for wall cribs: Wall cribs consist of wall, or rail pieces, which make up the face of the wall, and tie pieces, which are perpendicular to the wall face and extend back into the slope, anchoring the structure. Rail pieces are set parallel to the trail and ties are notched into them, at least two ties per rail, and set back into the bank. Ties should be at least thirty-six inches long and extend into the bank at least 2' (Figure 4.46 and 4.47).

As with retaining wall, the bottom tier of the crib should be buried at least eight inches below the natural level of the ground. Unless the terrain dictates a more vertical structure, crib walls should have sufficient batter to allow the rails to be “stepped” and soil and vegetation planted between each of them, or at least every two or three rails. An ideal width for the horizontal gap is one foot. Trees and shrubs should be planted if possible, as they will obscure the wall and their root structures will provide the bank with integrity when the log wall has disintegrated.

Implementation: Trail professionals should design log retaining walls and log cribs and calculate materials needed. Volunteers can haul in materials and assist with construction. Trail professionals should check tread cribs periodically to ensure that no logs have dislodged which may cause a hiker safety hazard. Such logs should be repaired or replaced as needed.

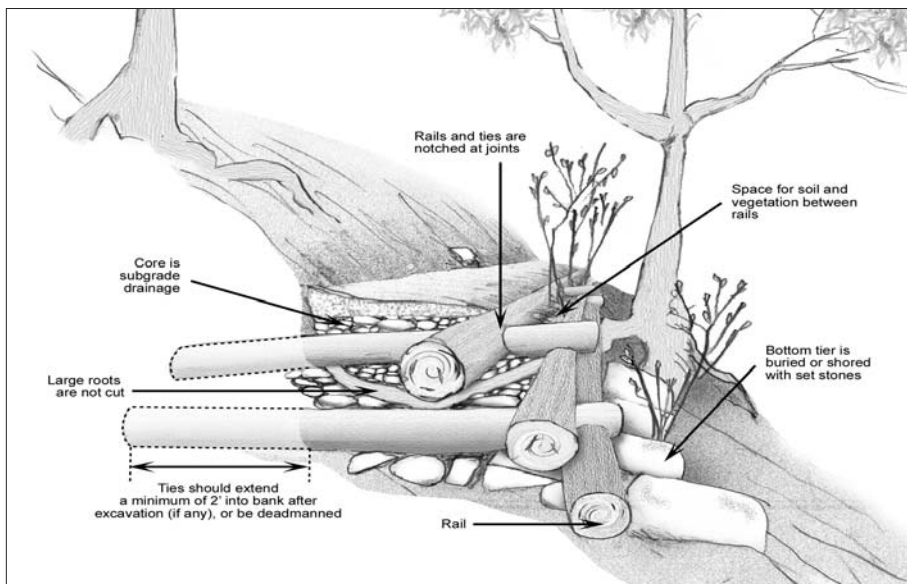


Figure 4.46. Detail of walled crib.

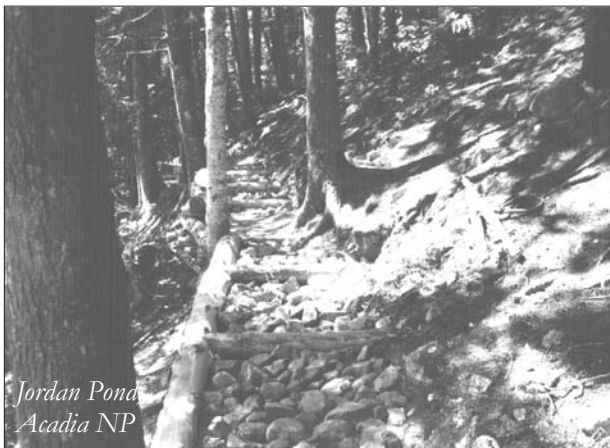


Figure 4.47. Log cribbing steps before receiving final top coat of gravel. The crushed rock that fills the crib facilitates trail drainage.

5.5 RETAINING STRUCTURES: Rehabilitate Stone Walls

A retaining wall may retain the treadway itself or a steep side slope. A laid wall contains stones set beside and on top of one another to create a vertical or substantially vertical face. The construction of laid walls uses established dry-laid stonework methods like maintaining tight contacts between stones, breaking the joints, and filling the core of the wall. The face of a laid wall may be smooth or rough. A laid wall with the stones set in even, horizontal rows is called a tiered wall. Laid walls are the strongest and most durable retaining walls, but also the most difficult to build properly.

A stone retaining wall with a single tier of stones may be either a sidewall or a coping retaining wall; either of these may be referred to as single-tier wall. Like a log sidewall, a stone sidewall is a low, single-tier retaining wall that retains a gravel treadway and is the type of wall used in conjunction with raised tread.

Issue: At Valley Forge NHP, there are retaining walls associated with trails that are in poor condition and need rehabilitation. Locations include:

- Mount Joy Trail J (Figure 4.48)
- Valley Creek Trail, near intersection with Mount Misery Trail B

Recommendation: Rehabilitate existing walls to preserve historic constructed features and to prevent loss of tread in steep areas.



Figure 4.48. The retaining wall on Mount Joy Trail J is roughly sixty feet long and needs rehabilitation by experienced stone masons.

Specifications: To reconstruct a wall from the base, the entire length and width of the retaining wall should be excavated at least six inches deep, until solid ground, free of organic material, is reached. The width of the base, and therefore the excavation channel, of a retaining wall should be at least one third the height of the completed wall. The ground at the bottom of the excavated area should be level or sloping slightly towards the interior of the wall, never sloping out.

The foundation is the first tier of the wall, which is partially or fully beneath the ground. It should project four inches or more beyond the face of the main wall. At least fifty percent of each front foundation stone should be directly beneath the main wall; these stones should be at least twelve inches long in the direction perpendicular to the wall. Foundation stones should provide a flat, or slightly insloping, top surface on which to lay the main wall.

For the wall face, stones should be chosen and laid so that an appropriate face is showing. If the desired face of a finished wall is to be smooth, then flat, even faces should show on each stone, and be flush at the fronts. If the face is to be rough, then rounded, sloping, or jagged faces can be used, and must be used at least part of the time.

The batter, or relationship of rise to run in the face of a retaining wall, should be determined in part according to the precedents of relevant historical work. However, the following general rules should be adhered to whenever possible:

- A three to one batter should be used for walls that retain active slopes, or soils which carry large amounts of running or freezing and thawing water.
- A four to one batter should be used for walls that retain soils which carry a moderate amount of water.
- A six to one batter may be used for walls that retain inactive, well drained soils with no unusual weight stresses, such as heavy equipment, placed on them.

Lay stones with the length back into the wall (header style) as often as possible. Larger stones may be laid with their lengths running with the face of the wall (stretcher style), but only if they provide at least eight to ten inches of width in the face of the wall. The tops of wall stones should provide level or generally backsloping surfaces on which to lay the next stones. Lay stones so that they transfer their weight into the wall below and the material behind, rather than away from the wall, which can cause stones to tumble out of the wall or lean away from their loads instead of back into them. Every seam created by stones laid side by side should be broken or spanned by a single stone which covers the seam and has contact with each of the stones beneath it. Unbroken joints are called “running joints” or “stack bonds” and are usually the first areas to fail in a retaining wall.

Headers are stones laid with their lengths perpendicular to the direction of the wall, which span the entire width of the wall, including the core, and ideally penetrate the material behind the wall. They serve to tie the wall together, front to back. The amount of headers needed in a given wall will vary according to the size of other stones in the wall, the availability of headers, the purpose of the wall, and so on, but two good rules of thumb are: 1) have at least one header in any three-square-foot area on the face of the wall, and 2) lay a header over any stones set “stretcher” style, with their lengths parallel to the wall’s face.

Wall stones should contact all stones below and beside them at one point at least. More contact points are unnecessary, as the amount of friction transferred will be the same either way. Contact should be at or towards the face of the wall for stability and to better retain core material. This technique is known as making a stone “strong to the face.” A stone should not tip forward when weight is put on it at the face.

Large stones should be used in the top course of the wall; all but the very largest (several cubic feet or larger) should be set header style. The specific pressures on the wall must be considered. The weight of larger stones serves to pin down the wall below them. Top stones are more vulnerable because they are not pinned down, and larger, header-style stones will be dislodged less easily by back pressure or hikers.

The core is the area between the face of the wall and the material being retained by the wall. Though unseen, it is an essential part of the wall, providing internal drainage, mass and structural cohesiveness to the wall. Poorly built core with small stones just thrown in behind the wall, or lack of a core, are perhaps the most common causes of retaining wall failure.

The core should be built using the largest stones first and then increasingly smaller stones until at least eighty percent of the core is packed with stone. Larger core stones should be laid so they span joints between stones in front of them in the face of the wall and stones below them. The end result is two walls, one built of the face stones and the other of core stones, that are woven together. The core should be packed behind face stones before additional face stones are laid on the next tier. Usually, a row of face stones is set, and then the core is packed behind them as a group (Figures 4.49 and 4.50).

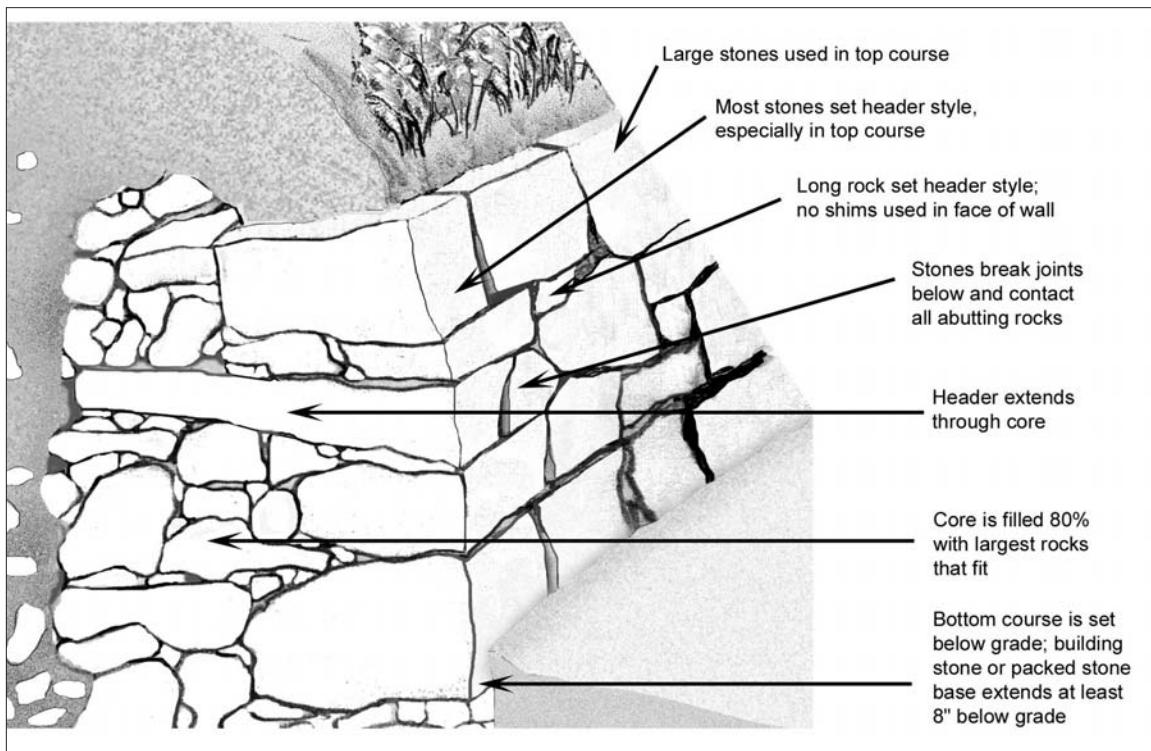


Figure 4.49. Specification for retaining wall construction from Acadia NP.

Implementation: Trail professionals with masonry skills should complete the stone work. Volunteers can gather stones from the surrounding area (without digging) as needed, or haul in materials as needed. Trail professionals or volunteers should maintain associated drainage structures and keep treadway above wall draining properly. Trail professionals should check the face of wall for voids and fill them. Fill voids in the interior of wall by stuffing small material through holes in the face. Volunteers can cut trees growing out of, directly in front of, or behind wall. Generally, cut all trees three inches or less in diameter and trees four to six inches in diameter if they are a threat to the wall. Avoid cutting trees greater than six inches in diameter unless they are an extreme threat to a historic wall's integrity, and if their removal will not cause further damage to the wall. Trail professionals should check for signs of wall failure: wall leaning out at the top, wall kicking out at the bottom, bulges in wall, loose or missing stones in wall, rusted or missing pins at base of wall. Repair and/or replace failed portions of a wall as necessary or these problems will worsen with time.



Figure 4.50. Though this dam wall on the Yellow Springs Trail Network has collapsed due to severe stream bed erosion and lack of maintenance, it was originally well-constructed: note the long headers stretching deep into bank, and the packing of core behind headers.



Figure 4.51. The wall above Mount Joy Trail J was originally well-constructed. Despite the middle section of the structure leaning outward due to the weight of the load behind the wall, overall it is still in fair condition.

